Designing Specific Tools to Enhance the Numeracy of Adults with Intellectual Disabilities

Lorraine Gaunt
Charles Sturt University
lgaunt@csu.edu.au

Design Research (DR) has been used to develop means of supporting mathematical learning for typically-developing students. This study investigated the use of DR to develop context specific tools to support adults with intellectual disabilities (ID) to improve their numeracy capabilities and engagement in daily tasks. Using observation and interview data, findings demonstrated increased engagement and participation in the numeracy demands of these tasks. Participants reported positive perceptions of improving competence and increases in independence. This study demonstrates the application of DR to the field of numeracy and adults with ID and the usefulness of context specific designed tools to support numeracy learning and independence.

Higher levels of numeracy lead to a better quality of life (Tout & Gal, 2015), however, adults with intellectual disability (ID) lack opportunity and expectation to engage with numeracy learning (Lambert & Tan, 2019). The term numeracy has evolved since first being coined by Crowther (Ministry of Education, 1959), and current conceptualisations of numeracy value more than just mathematical knowledge (Geiger et al., 2015). An ability to apply that knowledge in different contexts, a positive disposition towards using and applying mathematical knowledge, and a willingness to engage with and solve problems involving mathematics, are considered vital qualities of a numerate individual. Learners with ID need to have the opportunity to engage with numeracy learning at school and continue to have ongoing learning opportunities once they leave school.

Although research on inclusive school mathematics education for students with ID is ongoing (Bennison et al., 2020), research into numeracy learning opportunities for adults with ID is sparse (Prendergast et al., 2017). This study aimed to demonstrate one way of continuing to support numeracy learning for adults in work and social settings by investigating the way specifically designed tools could support numeracy learning and task engagement.

Background

What counts as numeracy has changed in an emerging technological environment (Bennison et al., 2020). Gaining a mastery of computations and fluency with numbers, previously seen as the foundation of school mathematics, has evolved into an understanding that being numerate requires the ability and the dispositions to use mathematics when solving problems in the context of home, community and work life (Geiger et al., 2015). Further, Faragher (2019) argued that mathematics for students with ID, should include the consideration that students now need to master the use of appropriate *tools,* such as calculators or smart phone apps, that may be used to support them to complete *basic mathematical skills* to develop more complex mathematical understandings. For example, students with ID may be able to learn to complete perimeter and area problems with their same age peers if they have access to calculators for the computation steps of the problem.

One model of numeracy that encompasses these conceptualisations is the 21st Century Model of Numeracy developed by Goos and her colleagues (Geiger et al., 2015; Goos et al., 2012). This model consists of five elements; *mathematical knowledge*, *tools*, *dispositions*, *context*; and *critical orientation*. Numerate individuals can use *mathematical knowledge* and select useful *tools* to solve problems and make sense of mathematical situations. In doing so, they demonstrate *positive dispositions* towards situations that involve mathematics.

2022. N. Fitzallen, C. Murphy, V. Hatisaru, & N. Maher (Eds.), *Mathematical confluences and journeys* (Proceedings of the 44th Annual Conference of the Mathematics Education Research Group of Australasia, July 3–7), pp. 218–225. Launceston: MERGA.

Additionally, the *context* of the problem can dictate the required mathematical knowledge and the available tools to support problem solving (Geiger et al., 2015). Finally, considered essential by Goos et al. (2012), is a *critical orientation* to numeracy; the ability to challenge and critically evaluate a situation involving mathematics. The 21st Century Model of Numeracy has been used to frame this study of developing numeracy for adults with ID.

Opportunity to participate in mathematical learning in different contexts is essential to developing numerate individuals (Schreiber-Barsch et al., 2020); however, for learners with ID, that opportunity is limited (Lambert & Tan, 2019). More than 30 years ago, Mastropieri et al. (1991) identified differences in the research on mathematics and numeracy education for learners with ID and typically-developing learners. Learners with ID were mainly exposed to a narrow range of mathematics curriculum, and teaching approaches constrained by behaviorists theories of learning. Mastropieri et al. (1992) noted the focus on constructivist approaches in mathematics education research for typically-developing learners and identified the need for mathematics research for students with ID to broaden the range of mathematics topics and variety of approaches. More recently, these results were confirmed by Lambert and Tan (2019) with the authors calling for significant changes in mathematics education research for students with ID that pays attention to "participation in general education mathematics" (p. 28) and documents students with ID in the "dominant pedagogical orientations in mathematics education" (p. 28.). Research that focuses on skills can lead to the segregation of students with ID into "lower quality mathematics instruction and may lead to low expectations of mathematical competence" (Lambert & Tan, 2019, p. 5).

Post school, the lack of opportunity and expectations continues with Schreiber-Barsch et al. (2020) suggesting that there are limited opportunities for adults with ID to continue learning when they leave school. This lack of opportunity to learn contributes to the lack of opportunities in employment and an "ordinary life" (Lysaght & Cobigo, 2014). Children with Disability Australia (CDA) commissioned a report on post school transition of children with disabilities in 2015. They found that people with disability in Australia "are only half as likely to be employed as people without disability" (CDA, 2015, p. 19). Thus, investigating ways of supporting adults with ID to continue learning post school need to be investigated.

Prendergast et al. (2017) suggested that adults with ID wanted to learn numeracy that is meaningful and useful to them and Schreiber-Barsch et al. (2020) identified learning in context as an important aspect of adult education. Thus, this study aimed to investigate ways of further developing adults' numeracy that is meaningful and useful to them by working with adults with ID in their work or social contexts to answer the following research question:

> *In what ways can DR support the development of specifically designed tools to support numeracy learning and task engagement for adults with ID in social contexts?*

Method

Qualitative research approaches enable the collection of rich data and are best suited to situations where a deep understanding of social contexts and phenomenon is required (Merriam & Tisdale, 2016). In this study, qualitative approaches were chosen because a rich analysis of the context of numeracy in the actual experiences of adults with ID was required. Additionally, Design Research (DR) is used in mathematics education to study mathematical learning and the development of tools to support learning (Cobb et al., 2003). In this study, designing tools that specifically targeted the participants' learning in the context of their daily tasks was required, thus DR was adapted to the context of adult learning.

Using a qualitative research design, observations and interviews were conducted with four adults with ID in their work or social settings to determine participants' numeracy needs and design individual goals. Based on these goals, DR was then used to develop, trial and refine task specific tools to support numeracy learning. Participants were three male and one female

adult with ID ranging in ages from 19 to 41 years. This paper draws on data from two participants competing in ten pin bowling, Ben, a 19-year-old male and David, a 41-year-old male (pseudonyms). The study comprised two phases.

Phase 1 of the study comprised 6–8 one-hour long audio recorded observations (Merriam & Tisdale, 2016) over 7–12 weeks to document numeracy demands of chosen tasks of participants. Interviews with participants and significant others, such as support workers, were conducted at the end of Phase 1 to clarify researcher interpretations of observation data and provide participants with a voice. These data were used to identify learning goals and design tools to support participants' numeracy development in Phase 2, a further 11–13 one-hour long audio recorded observations over 16 weeks. Ongoing analysis throughout Phase 2 supported the design and modification of the tools. Phase 2 observation data were analysed with further interview data collected at the end of Phase 2, to determine the effectiveness of the designed tools to support participation in the numeracy demands of the chosen tasks.

Results

In this section, using data from Ben and David at the bowling alley as evidence, the process of designing individualised tools to support learning is discussed. Original design of tools to support learning was based on observation and interview data from Phase 1 of the study, and then refined through iterations of the DR cycle, illustrated in Figure 1.

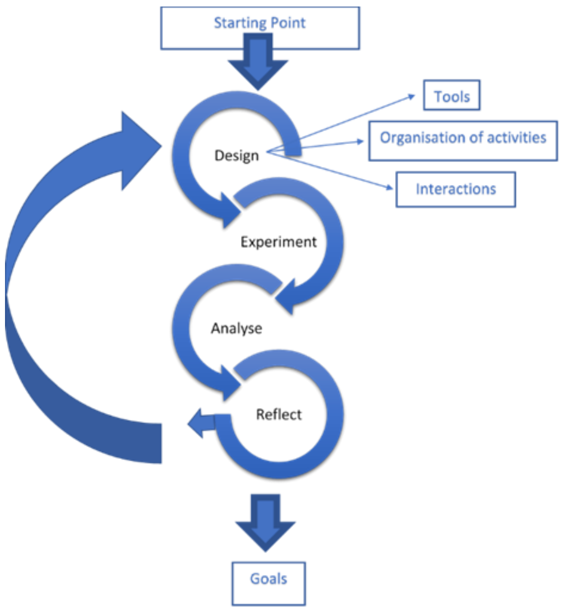


Figure 1. Design research cycle.

Using data from Phase 2 of this study in the context of the bowling alley, the development of viable tools using the DR cycle will be demonstrated. A *Scoresheet* was the tool designed to support Ben and David to reach their goal of being able to determine their current running total when strikes and spares were scored. This example was chosen for this paper as a number of iterations of design were required before the resulting tool supported these participants' progress towards their goal at the bowling alley.

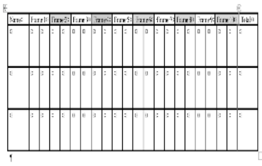
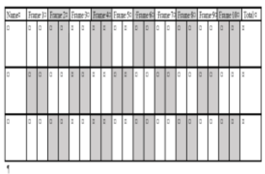
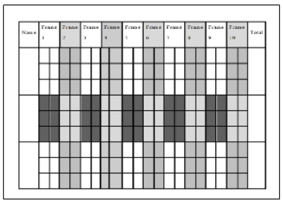
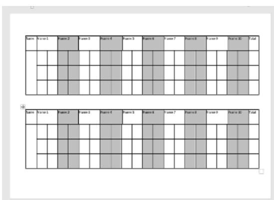
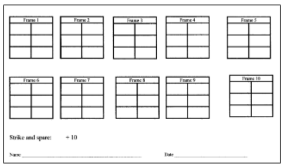
Designing a Tool at the Bowling Alley: The Scoresheet

The starting point for this DR experiment was the identification of the goal. Identification of goals in this study were discussed in a previous publication (Gaunt et al., 2019). Based on the analysis of Phase 1 data, the identification of the goal for Ben and David was to be able to

calculate their running total when a spare or strike was scored. The next step was to determine the mathematical knowledge to calculate the running total after scoring a spare or a strike (add 10 to the current score) and the current capabilities of the two participants. From Phase 1 data, Ben and David demonstrated strength in reading, comparing and understanding numbers (observed 85 times during Phase 1 with 100% accuracy from both bowlers). Both bowlers showed difficulties in determining their current score using mental calculations (out of 25 attempts during Phase 1 observations, 11 were correct and 14 were incorrect). Additionally, remembering information, such as how many points they scored for a strike, was difficult (Out of 16 attempts, only David answered correctly on one occasion). To support numeracy learning, a *Scoresheet* was designed to be used with the support of a *Calculator*.

Designing a visual *Scoresheet* similar in layout to the scoreboard would facilitate the bowlers' understanding and use of the tool. Design 1 was developed (see Table 1) and trialled by the researcher. After analysing and reflecting on the design during observations, two further iterations of the DR cycle resulted in Design 3, the first design trialled with participants.

Table 1
Scoresheet Design

Experiment: Design no	Design	Analyse: supports	Analyse: difficulties	Reflect: Considerations for next design
Design 1 Trailed by researcher		Can record scores exactly as on score board	Difficult to track across score sheet	Provide alternate shading of frames
Design 2 Trailed by researcher		Can track across scoresheet	If participant scores a strike, nowhere to record interim score	Include extra row to record score
Design 3 First design shown to participants		Frames identifiable with shading and space to record interim score after strike.	A significant amount of recording would be required by each bowler if they were to record all bowlers scores	Each bowler only records their score
Design 4: First design used by participants		Larger boxes and bowlers only recorded their own score	Boxes too small. Difficulty tracking across the scoresheet. Difficulty remembering strike and spare = +10.	Separate frames and make boxes larger. Add visual prompt
Design 5 Final design		Frames separated. Boxes larger. One game per side of page		

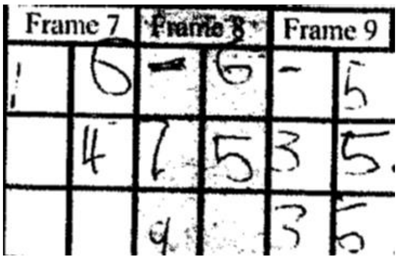
The Design 3 *Scoresheet* was modelled on the scoreboard and provided space to record the scores for the usual three bowlers for each game (only two of the bowlers were participants in the study). Each frame was distinguishable by the use of alternate shading, and within each

frame, there were three rows instead of the two found on the scoreboard to allow the recording of the interim total if a spare or strike was scored.

During Observation 1 of Phase 2, the researcher demonstrated the *Scoresheet* to David and Ben. Both bowlers checked in after each turn and were shown how to record their scores, by demonstrating the use of the calculator to add 10, and where to record scores on the scoresheet. During this trial, it was conjectured that simplifying the amount of recording required for each person would further support the bowlers in completing their *Scoresheet* independently, allowing them to concentrate on only their score for recording purposes. The subsequent Design 4 *Scoresheet* (see Table 1) was thus intended for just one bowler to record the usual two games that were completed for each competition.

Design 4 was the first design where Ben and David completed their own scores. When the bowlers began using their *Scoresheets*, it became apparent that Design 4 did not support the activity well. Figures 2 and 3 show copies of a section of the recorded *Scoresheet* for Ben and David respectively, compared to the same section of the researcher's master *Scoresheet*.

A Section of Ben's *Scoresheet*



Master *Scoresheet*

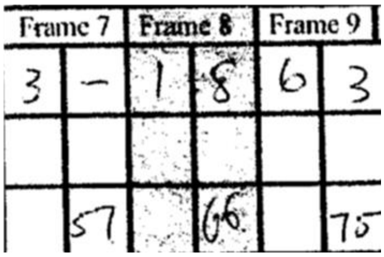
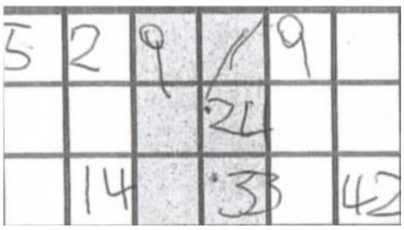


Figure 2. First trial of Design 4 Scoresheet for Ben.

As Figure 2 shows, Ben had difficulties keeping the numerals within each box, and distinguishing the different frames on the *Scoresheet*, even though they had been alternately shaded. His written numerals were quite large and even though the *Scoresheet* covered the top half of the A4 page in landscape (each box was 12 mm x 14 mm), Ben struggled to fit the numerals within the boxes. When offered help by pointing to the correct boxes on the *Scoresheet* for the next score, Ben often rushed ahead to write his scores in, without assistance. In doing so, he had difficulty following the table setup, and as a result, Ben's final *Scoresheet* carried no resemblance to the master score sheet for his game (see Figure 2).

A Section of David's *Scoresheet*



Master *Scoresheet*

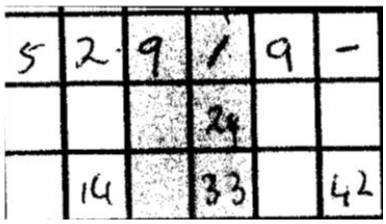


Figure 3. First trial of Design 4 scoresheet for David.

David was hesitant in writing his numerals. He would look at the scoreboard (or *Calculator*), and back at the *Scoresheet*, and then back to the scoreboard repeatedly, before writing the number down. However, when asked what his score was, he could answer

immediately. David had difficulty finding where to write each score. It was not sufficient to point to the sheet and say, 'write your score in here' and then move away. The researcher had to hover the pen over the correct box and wait for David to check the scoreboard a few times before he wrote the number in the box. If the pen was moved away, David did not know where to write his score. As Figure 3 shows, a dot was put in the empty box to add a further visual support and indicate the correct place. However, this strategy was unsuccessful as it was even more difficult for David to fit his numbers in the square as he would not write the number over the dot. Despite these difficulties, Figure 3 shows that David's score sheet accurately matched the master *Scoresheet* for this section of the game.

Additionally, Ben and David had difficulty remembering the number of points to add in order to calculate their running total (10). During this observation, David responded with "*seven points*" three times, 10 once and "*I don't know*" once. When he scored a spare, Ben responded with the first bowl of his spare (observed twice out of two times a spare was scored). On the one occasion Ben scored a strike, he responded, "*I don't know*."

The ongoing analysis and reflection of participants' activities with the designed tool facilitated the subsequent modifications within the DR cycle (Figure 1). The difficulties presented by the participants in using the *Scoresheet* informed specific adjustments that were subsequently trialled to accommodate the needs of these adult learners with ID. The next re-design of the *Scoresheet* (Design 5) included the enlargement and separation of each frame. Additionally, the *Scoresheet* was double sided so only one game was recorded on each side. This allowed for larger boxes to record scores (each box was 18 mm x 14 mm). It was conjectured that this would both support the participants in finding the appropriate box more easily and allow for writing larger numerals. Additionally, further scaffolding was added by including written instruction at the bottom of the *Scoresheet* to add 10 for spares and strikes.

Design 5 of the *Scoresheet* assisted both Ben and David with more accurate recording of the scores. The larger boxes made it easier to keep large numerals within the boxes. Separating each frame made it easier to track frames in the game. Ben required some assistance when recording scores for spares and strikes, but he could copy his scores from the scoreboard independently. The process of separating each frame, made it easier for Ben to independently follow the *Scoresheet*. Both participants stated that Design 5 was much easier to follow. This was the final design of the *Scoresheet* used during Phase 2 of the research.

The design of the scoresheet supported both participants in reaching their goal of being able to calculate their running total when they scored a spare or a strike. While both participants achieved their numeracy goal, the impact of that achievement went beyond the simple ability of knowing their current score in the game. An increase in participation and engagement was observed as the participants progressed in their skills.

During Phase 1, particularly if a number of spares or strikes had been scored in a row, estimating who was currently in the lead was difficult. In such situations, both bowlers were frustrated by not knowing the current score. For example,

1. *Ben*: [Bowls 8 and checks his score] *64, yes!*
2. Bowlers congratulate Ben. One person has bowled two strikes and scoreboard is inaccurate.
3. *Ben: Thanks, but I don't know what your score is!*
4. The other bowler then has his turn and bowls a third strike.
5. *Ben: Well done buddy! A turkey. Turkey dinner tonight. We still don't know what your score is, but I think you are winning!*

Transcript 1: Phase 1, Bowling, Observation 1

This excerpt shows the frustration that was evident (see Line 3), particularly when a number of spares or strikes were scored in a row (Line 5). Frustration with not knowing the score was observed 39 times during Phase 1. In those situations, the bowlers could not calculate, or estimate accurately, the current score. During the game discussed in transcript 1, the bowler in

question scored four strikes in a row. For 50% of the game, the scoreboard showed incomplete information and bowlers were unsure of the score until the last frame.

Given the significant delay in the scoreboard displaying the score, and the complexity of updating the scores mentally, David and Ben were often unaware of their score and who was winning. Hence, while Ben and David made use of the scoreboard, it was not always sufficient for their purposes. The *scoresheet* was a tool designed to support them to calculate and record their scores, but knowing their scores influenced both interactions with each other and their engagement and participation in the game.

As the participants became independent in calculating their scores, the focus of their conversations changed from discussing the score and guessing who was winning to knowing their place in the game and discussing what was needed to maintain the lead or catch up.

1. *Ben*: [scored 8 (4 and 4)] *I got 4 and 4 and now I have 48* [wrote independently].
2. David scored a strike and the onlookers cheered.
3. *Researcher: Well done!* [To third bowler] *I wonder if David has caught up to you.*
4. *David: Yep, I reckon I have, I'll work it out* [wrote X on *Scoresheet,* got *Calculator*] ….
5. *David:* [puts "+10 =" in *Calculator*] *65! I've nearly caught up to* [bowler] *He is on 71.*
6. *Ben:* [Came to write in score] *I have 49, I am not too far behind.*
7. *David:* [Bowled 8 and wrote score in] *73, Now I am in front!*
8. *Ben: Yep, you are but I am not far behind.*
9. *David*: *49, you have some catching up to do.*
10. *Ben: I might need a strike then!*

Transcript 2: Phase 2, Bowling, Observation 10

Transcript 2 demonstrates the focus of conversations on scores with bowlers now discussing who they *knew* was winning (Lines 5–9) and what they needed to do in their own game to change that (Line 10). This focus is different from the earlier observations (Transcript 1) where conversations often focused on who the players *thought might* be winning.

Discussion

This research demonstrates the usefulness of DR to frame the design of tools to support the achievement of numeracy learning goals for adults with ID. In DR in mathematics education, the design research cycle focusses on the tools, activities and other means that would support students' progress from their current understandings towards a goal, usually predetermined by the curriculum (Cobb et al., 2003). In contrast, when using DR to support the individual numeracy learning of adults with ID, goals are designed for the context of the adult's activity (Gaunt et al., 2019), and the design of tools that supports adults to achieve numeracy goals leads to adults with ID demonstrating greater participation and engagement in the activity or task. This was seen in the changes in the conversations about scoring demonstrated in Transcript 2.

In designing tools to support the adult learner with ID, it is important to design and trial these tools within the context in which the learner requires those tools (Faragher, 2019; Prendergast et al., 2017). The design process (Figure 1) of trialling tools, with ongoing analysis and reflection of the impact and ease of use, is an important factor in the resulting successful development of the tool. While the mathematical aspects of the task are the focus of the initial design of the tool, consideration of the adult learner as a whole is a vital aspect in the design process for a successful outcome. This was seen in the enlargement and separation of the boxes for recording scores on the scoresheet. The design research cycle has much to offer learners with ID and has been shown to be valuable in supporting adults with ID in this study.

For adults with ID, continued learning post school supporting increased participation and engagement in a task or activity can lead to greater independence in, or enjoyment of, that task.

Cuskelly et al. (2021) identified that the benefits of continued learning for adults with ID go beyond simply achieving a learning goal, and include better outcomes in employment health and friendships. While the current study does not provide sufficient evidence to make definitive claims, the increases in engagement and participation indicated by Transcript 2, show a different aspect to the interactions between the bowlers. Their camaraderie, competition and friendship are on display in the transcripts. The increase in participation and engagement demonstrated in this study is an area that warrants further research.

This study has shown that designing specific tools to support numeracy learning in specific contexts may have benefits beyond the achievement of a learning goal. Although access to continued learning post school is still limited for adults with ID, the benefits shown by this research and others (c.f. Schreiber-Barsch et al., 2020) demonstrate the value in continuing to advocate and research more opportunities for adults with ID to promote post-school learning.

References

Bennison, A., Goos, M., & Geiger, V. (2020). Utilising a research-informed instructional design approach to develop an online resource to support teacher professional learning on embedding numeracy across the curriculum. *ZDM Mathematics Education*, *52*(5), 1017–1031. https://doi.org/10.1007/s11858-020-01140-2

Children with Disability Australia (CDA). (2015). *Post school transition: The experiences of students with disability.* https://www.cyda.org.au/resources/details/85/post-school-transition-the-experiences-of-students-with-disability

Cobb, P., Confrey, J., diSessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher*, *32*(1), 9–13. https://doi.org/10.3102/0013189X032001009

Cuskelly, M., Moni, K., McMahon, M., Jobling, A., Lloyd, J., & Leggatt-Cook, C. (2021). Futures of adults with intellectual disability: Staff expectations. *Journal of Intellectual and Developmental Disability. 46*(4), 319–328. https://doi.org/10.3109/13668250.2020.1814490

Faragher, R. (2019). The new “functional mathematics” for learners with Down Syndrome: Numeracy for a digital world. *International Journal of Disability, Development and Education*, *66*(2), 1–12. https://doi.org/10.1080/1034912X.2019.1571172

Gaunt, L., Visnovska, J., & Moni, K. (2019). Designing individual goals to enhance the numeracy of adults with intellectual disabilities. In G. Hine, S. Blackley & A Cooke (Eds.), *Mathematics Education Research: Impacting Practice* (Proceedings of the 42nd Annual Conference of the Mathematics Education Research Group of Australasia), pp. 292–299. Perth: MERGA.

Geiger, V., Goos, M., & Forgasz, H. (2015). A rich interpretation of numeracy for the 21st century: A survey of the state of the field. *ZDM*, *Mathematics Education*, *47*(4), 531–548. https://doi.org/10.1007/s11858-015-0708-1

Goos, M., Dole, S., & Geiger, V. (2012). Numeracy across the curriculum. *Australian Mathematics Teacher*, *68*(1), 3–7.

Lambert, R., & Tan, P. (2019). Does disability matter in mathematics educational research? A critical comparison of research on students with and without disabilities. *Mathematics Education Research Journal*, *32*(1), 5–35. https://doi.org/10.1007/s13394-019-00299-6

Lysaght, R., M., & Cobigo, V. (2014). Enhancing the quality of life of marginalized populations through employment. *International Public Health Journal*, *6*(4), 301–310.

Mastropieri, M., Bakken, J., & Scruggs, T. (1991). Mathematics instruction for individuals with mental retardation: A perspective and research synthesis. *Education and Training in Mental Retardation*, *26*(2), 115–129.

Merriam, S., & Tisdale, E. (2016). *Qualitative research: A guide to design and implementation* (4th ed.). Jossey-Bass.

Ministry of Education. (1959). *Crowther Report: 15–18: A report of the Central Advisory Council for Education (England)*. HMSO. http://www.educationengland.org.uk/documents/crowther/

Prendergast, M., Spassiani, N. A., & Roche, J. (2017). Developing a mathematics module for students with intellectual disability in higher education. *International Journal of Higher Education*, *6*(3), 169–177.

Schreiber-Barsch, S., Curdt, W., & Gundlach, H. (2020). Whose voices matter? Adults with learning difficulties and the emancipatory potential of numeracy practices. *ZDM Mathematics Education*, *52*(3), 581–592. https://doi.org/10.1007/s11858-020-01133-1

Tout, D., & Gal, I. (2015). Perspectives on numeracy: reflections from international assessments. *ZDM Mathematics Education*, *47*(4), 691–706. https://doi.org/10.1007/s11858-015-0672-9